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SYSTEM OF SYSTEMS OPERATIONAL ANALYSIS WITHIN A COMMON OPERATIONAL CONTEXT

MORS 2005 Conference

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JHU/APL

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Objective

- To develop a process to analyze the value of a system of systems (SoS) effort towards mission accomplishment
  - This example will focus on a surface warfare (SUW) scenario in the littorals for describing the process and example analysis
- Provide a methodology to utilize multiple tools towards generating a solution to the given problem set

Agenda

- Problem Space

- SoS Analysis Process

  – Scenario setup

  – Tie-in with other tools

  – Execution & analysis

- SUW Example

- Conclusion

Problem Space

- Within an SUW scenario, red platforms will attempt to arrive unhindered to their objective (typically a blue high value location)

- The blue objective is to successfully intercept these red platforms either prior to start or during the red transit
  - This problem looks at the transit phase, not at pre-emptive strike efforts
  - Blue surveillance platforms and interceptors will be stationed along the expected threat axis to detect and track the target, while directing blue interceptors towards the target
  - Blue stationing may depend on defended area requirements, red stand-off ranges, available locations, etc.

Legacy Solution Space

- The legacy solution space will require multiple blue surveillance platforms to perform detection and tracking of the target, directing blue interceptors towards the target

- The legacy architecture allows independent detection and tracking efforts, with no fuzed tactical picture capability

The overall picture is only as good as the best ONE surveillance platform capability!

Future Solution Space

- Explore the utility of a system of systems approach

- Each blue surveillance platform contributes its detection/tracking of the red threat, combining these tracks into one shared picture

- The hypothesis is that a few networked sensors are better than many independent sensors

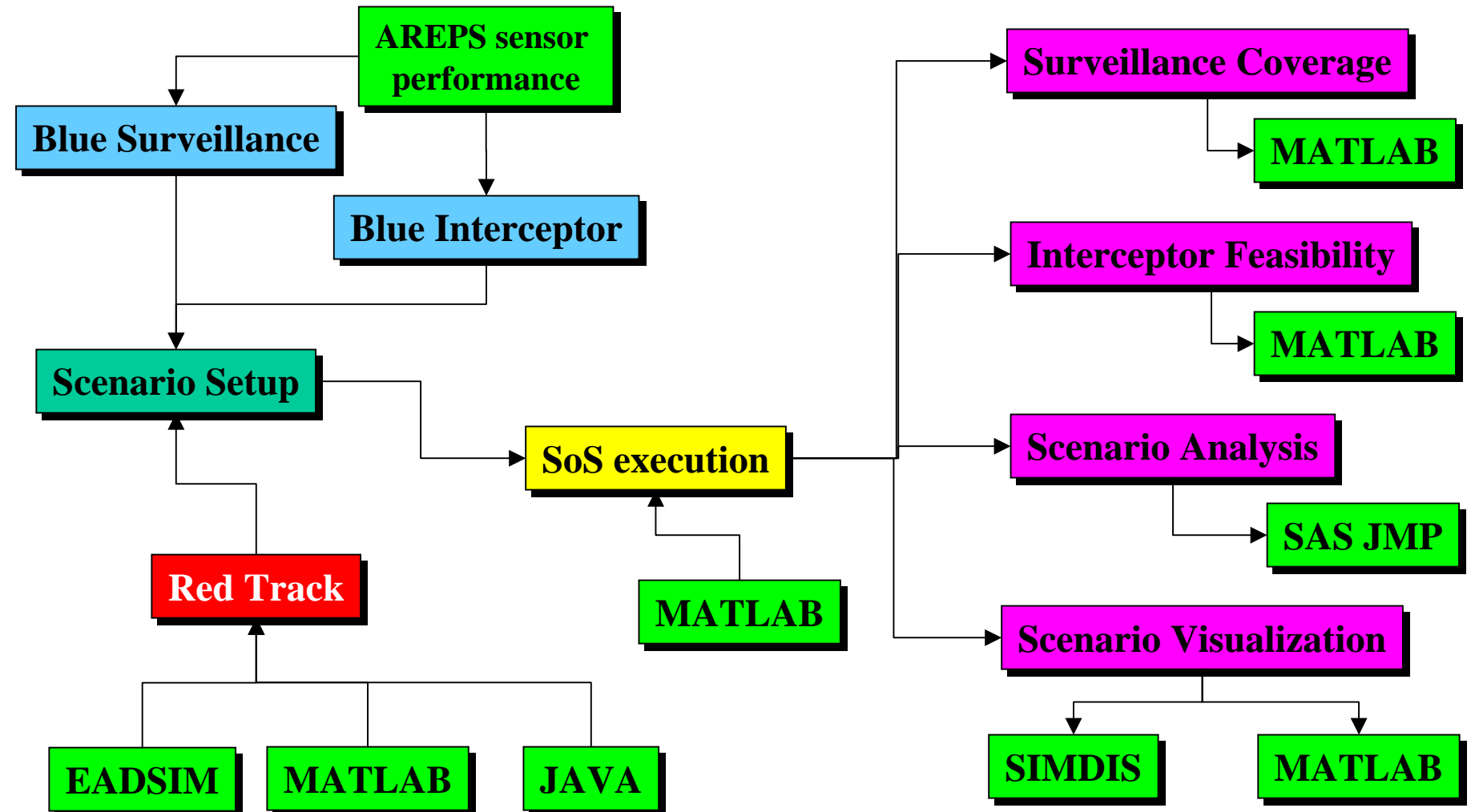- This presentation will develop a methodology for quantifying the added value of the future solution space

SoS Development Process

- Construct a framework of multiple applications to contribute towards a SoS representation
  - SoS architecture
  - Scenario setup
    - Platform / sensor representations
  - Scenario execution
  - Assessment functions (highlighted in the example)
    - Surveillance coverage
    - Interceptor feasibility
    - Significant factors in the scenario
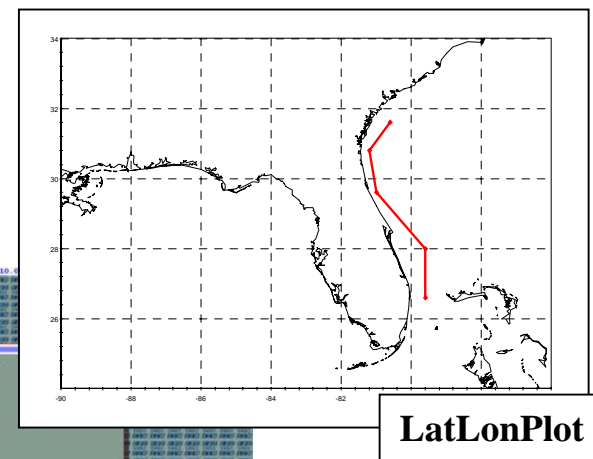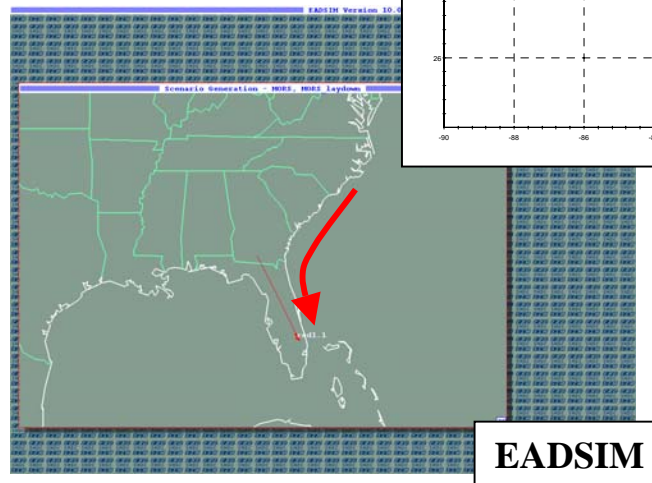   - Hypothesis investigation

SoS Architecture

Scenario Setup

- Start of the problem
- Define red path
- Define blue surveillance and interceptor attributes
- Define the desired response
  - Ex: tradeoffs between speed and sensor performance, first-order assessment of asset placement, etc.

Red Platform Attributes

- Develop a path for the red platform to transit during the scenario

- Construct a path that allows an opportunity to exercise the SoS

  – A variety of tools may be used

  – EADSIM, LatLonPlot, maps, etc.

  – Starting and ending points

  – Speed of platform

LatLonPlot

EADSIM

Blue Surveillance Attributes

- Develop a matrix of what the blue surveillance platform is capable of:
  - Number of surveillance assets
  - Location during the scenario
  - Capabilities of sensor
    - Range
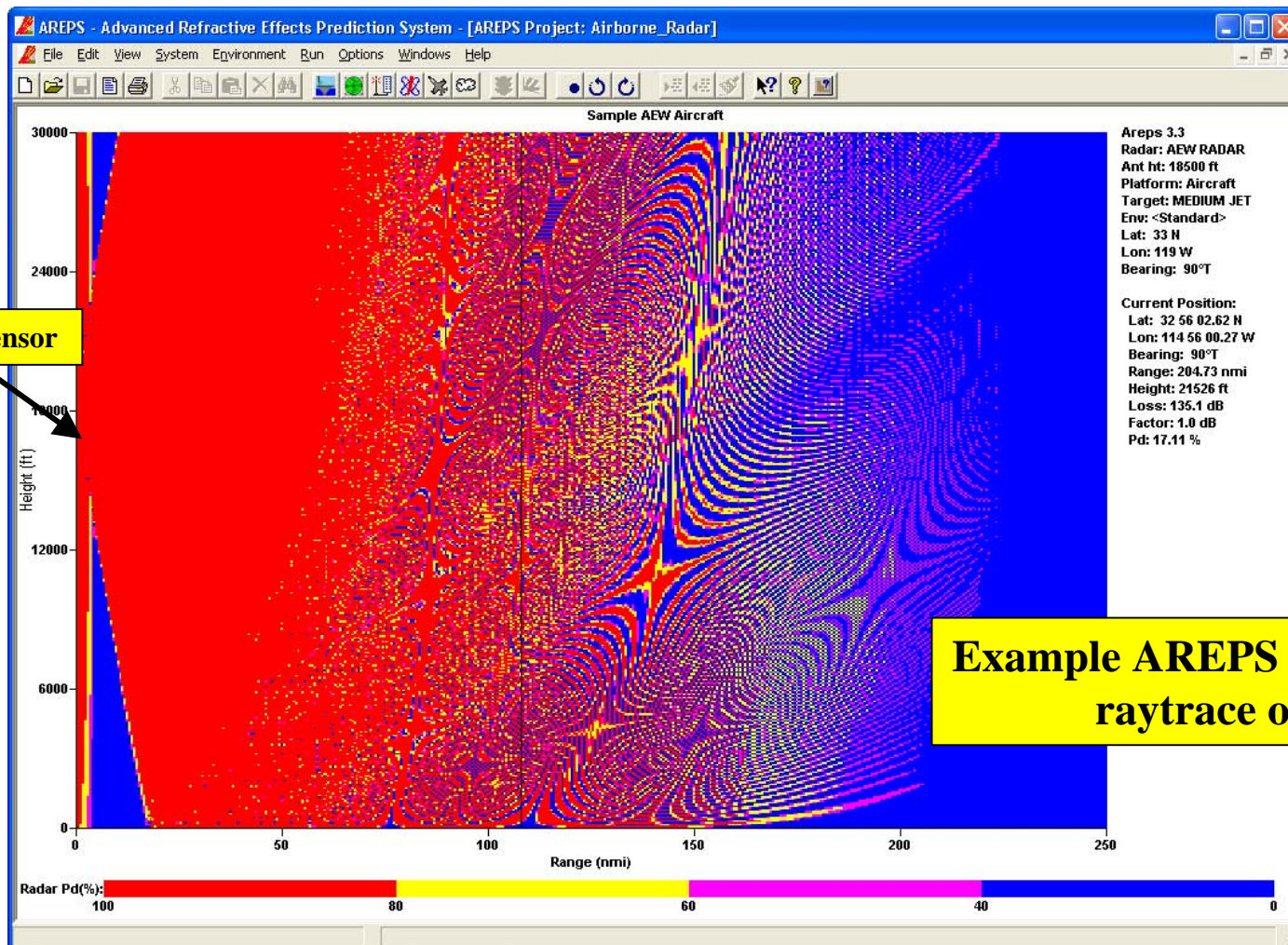   - Scan rate
    - Probability of detection

Sensor Information from AREPS

- The use of the Advanced Refractive Effects Prediction System (AREPS) produced by SPAWAR provides the effects of specific radar parameters to build the characteristic AEW or interceptor radar

- Provides Probability of Detection vs. Range plots

- Import into MATLAB to curve-fit for later use
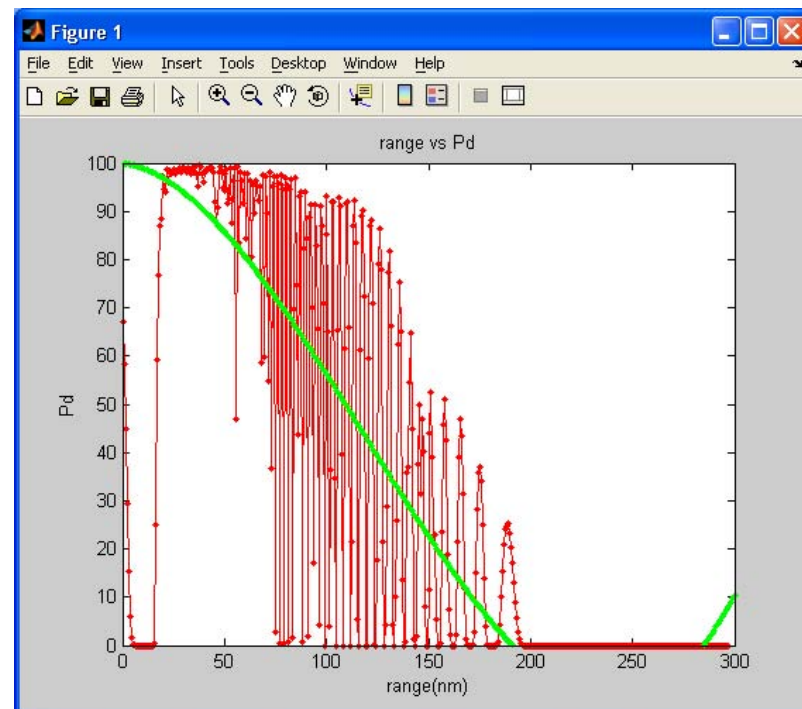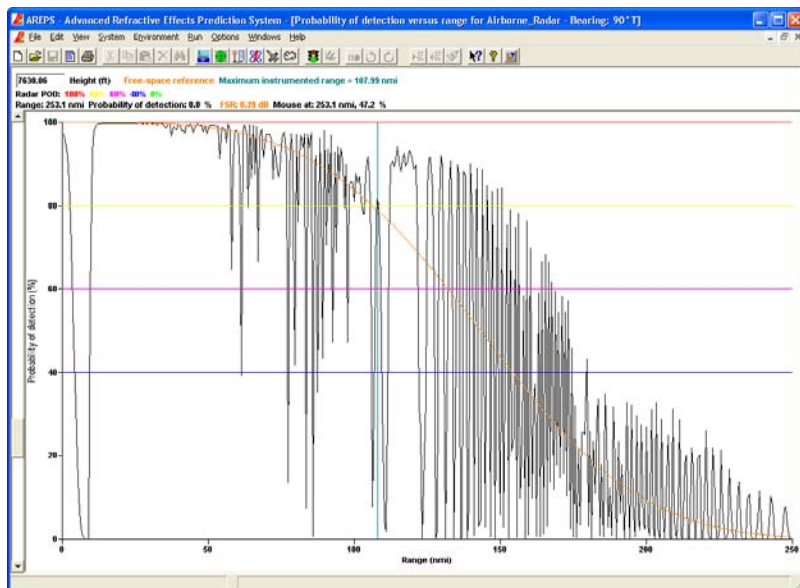
Sensor Information from AREPS

Elevated Sensor

Example AREPS Pd vs. Range raytrace output

Sensor Information from AREPS

Build the sensor capability

Probability of Detection vs. Range data from AREPS

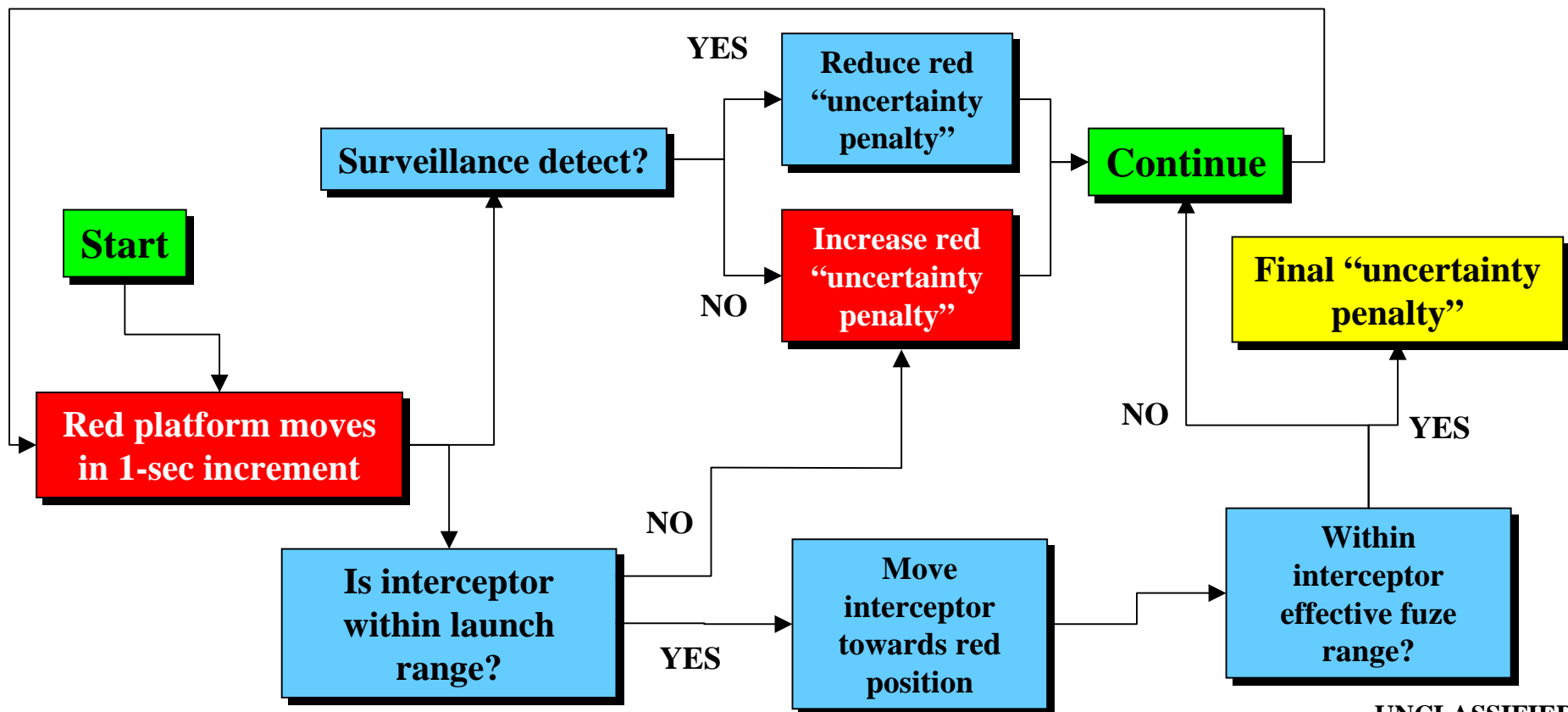Import data into MATLAB after curve-fitting

Blue Interceptor Attributes

- Develop a matrix of what the blue interceptor is capable of:
  - Number of interceptor assets
  - Location during the scenario
  - Capabilities of interceptor sensor
    - Maximum effective range
    - Scan rate
    - Probability of detection
    - Effective (fuze) range
  - Range of initiation of interceptor

Scenario Execution Example

- MATLAB-based script to accept scenario setup files
- Time-stepped simulation
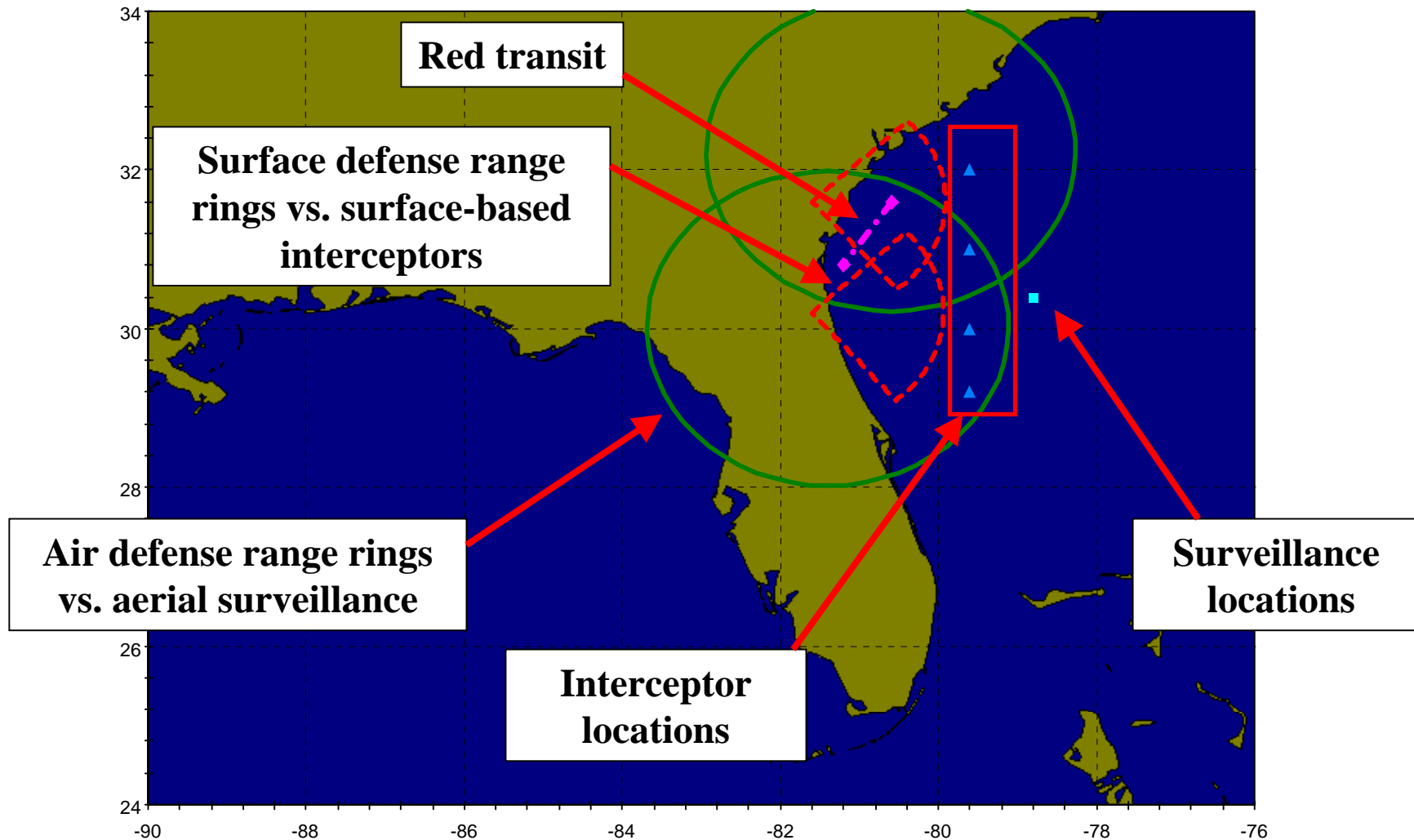

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Surface Warfare (SUW) Application

- Apply similar methodology towards a surface warfare (SUW) mission area problem
- Example: red surface platforms are transiting underneath the umbrella of red air and surface defenses, posing a problem of surveillance and interceptor placement for successful red intercept.
- Determine the desired response
    - "Final uncertainty penalty" based on a single surveillance platform and multiple interceptor positions
- Given the following options
    - Surveillance sensor performance and scan rates
    - Interceptor seeker performance and scan rates
- Determine what combination of variables are most significant to the problem
- Investigate hypothesis of multiple sensors to add value to the situation
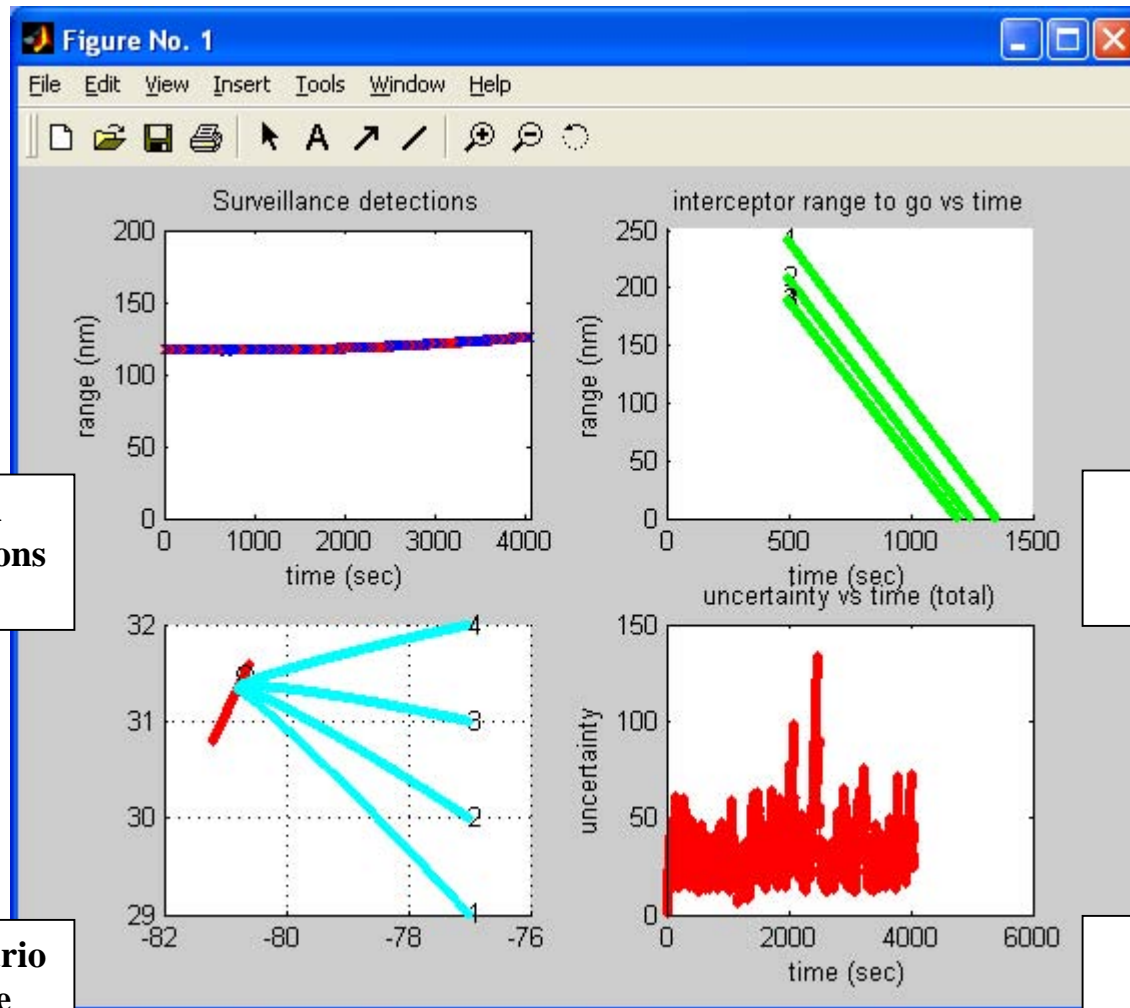
SUW Application

Red transit

Surface defense range rings vs. surface-based interceptors

Air defense range rings vs. aerial surveillance

Interceptor locations

Surveillance locations

Example Output (Surveillance & Interceptor)

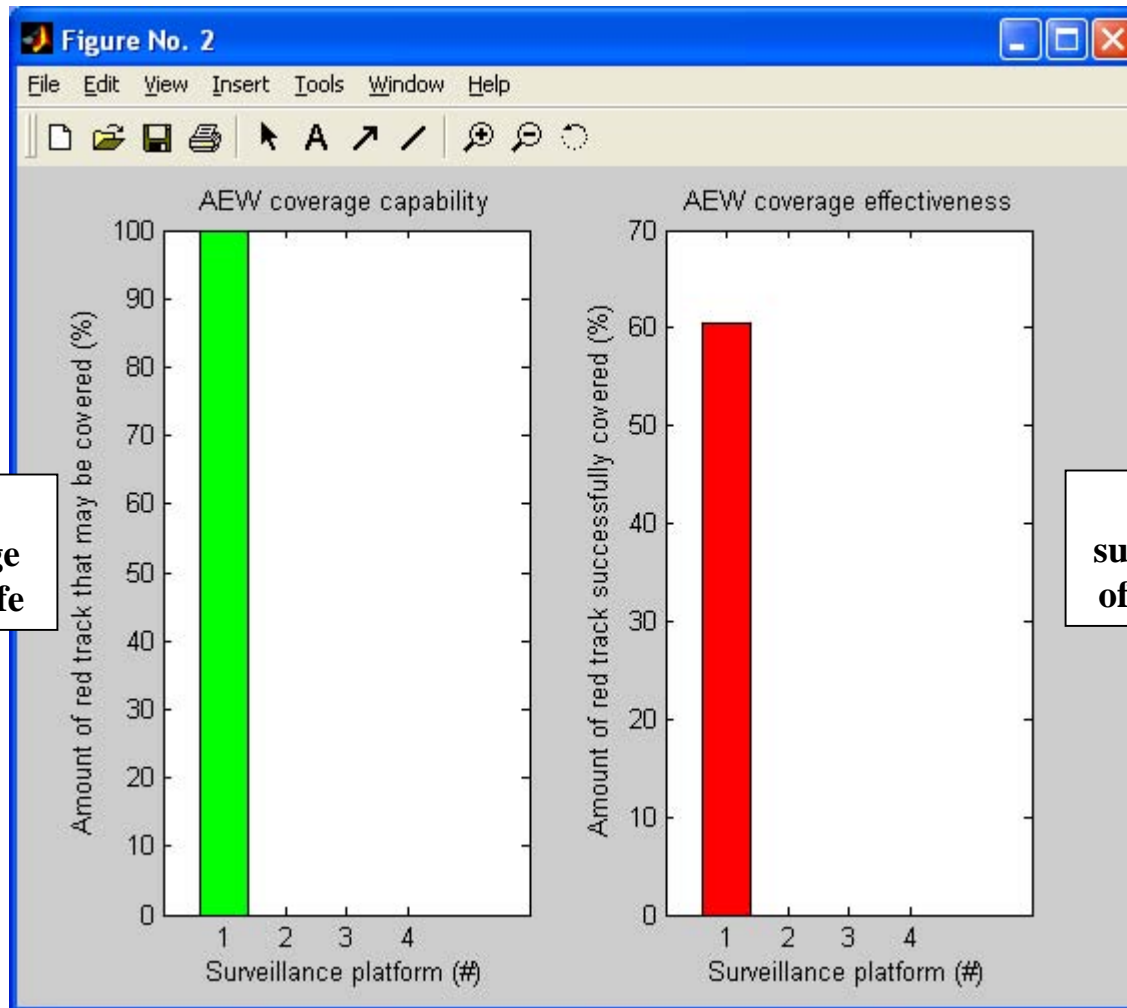Plot of successful surveillance detections during scenario

Plot of interceptor range to tgt during scenario

Quick-look of scenario (red track vs. blue tracks)

Plot of "uncertainty penalty" vs. time during scenario
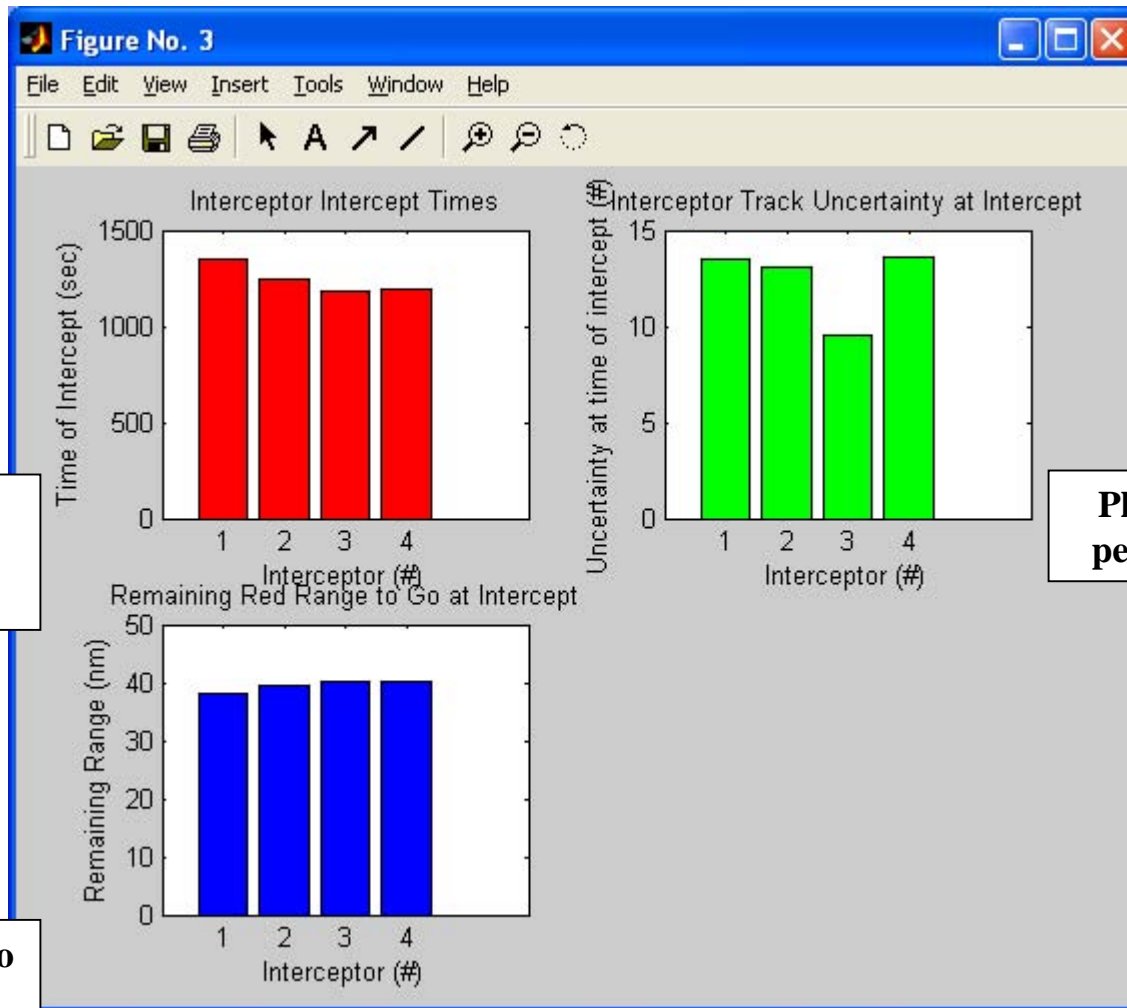
Example Output (Surveillance)

Plot of available surveillance coverage of entire red track life

Plot of successful surveillance detections of entire red track life
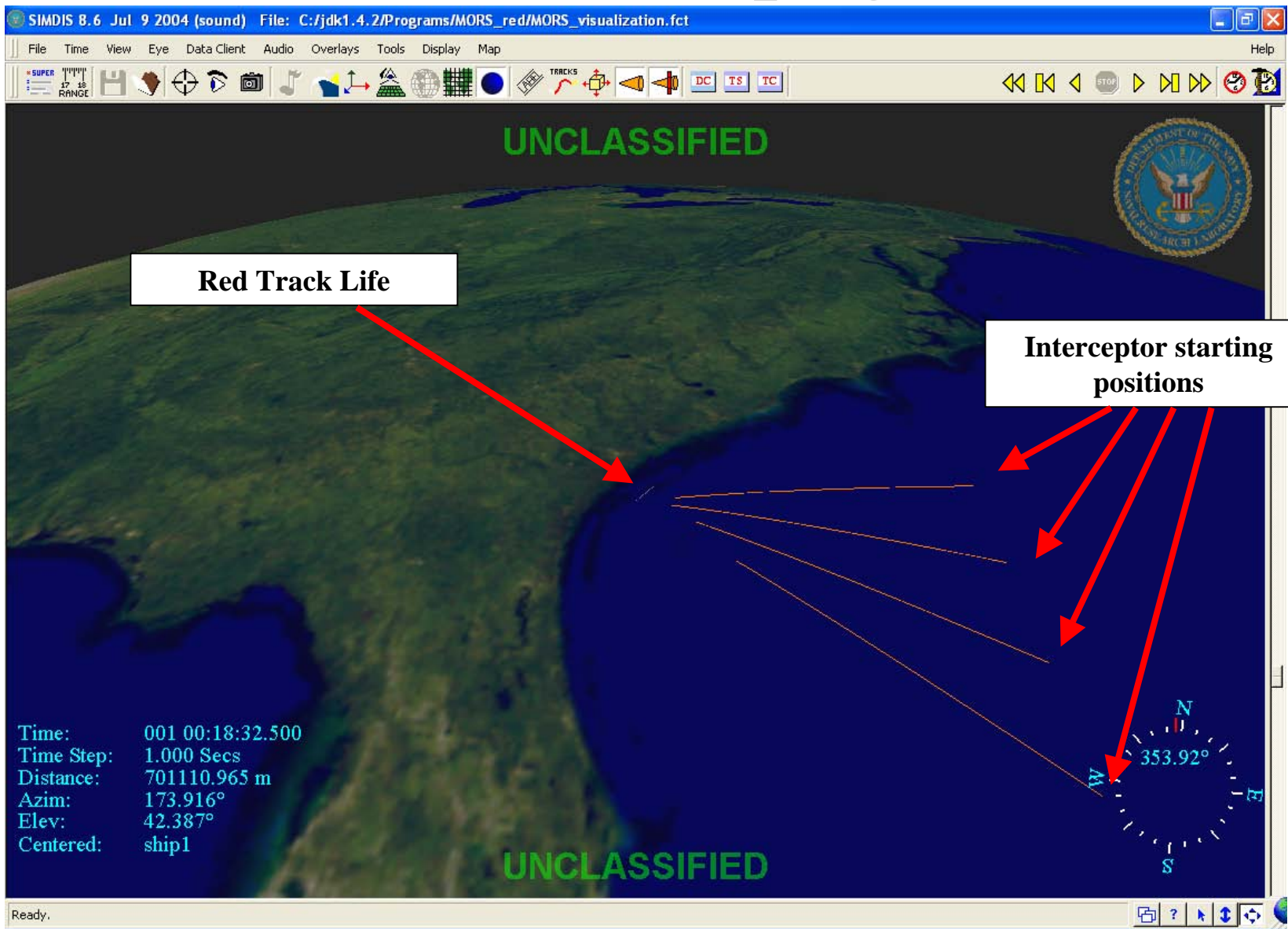
Example Output (Interceptor)

Plot of interceptor intercept during scenario

Plot of "uncertainty penalty" at intercept
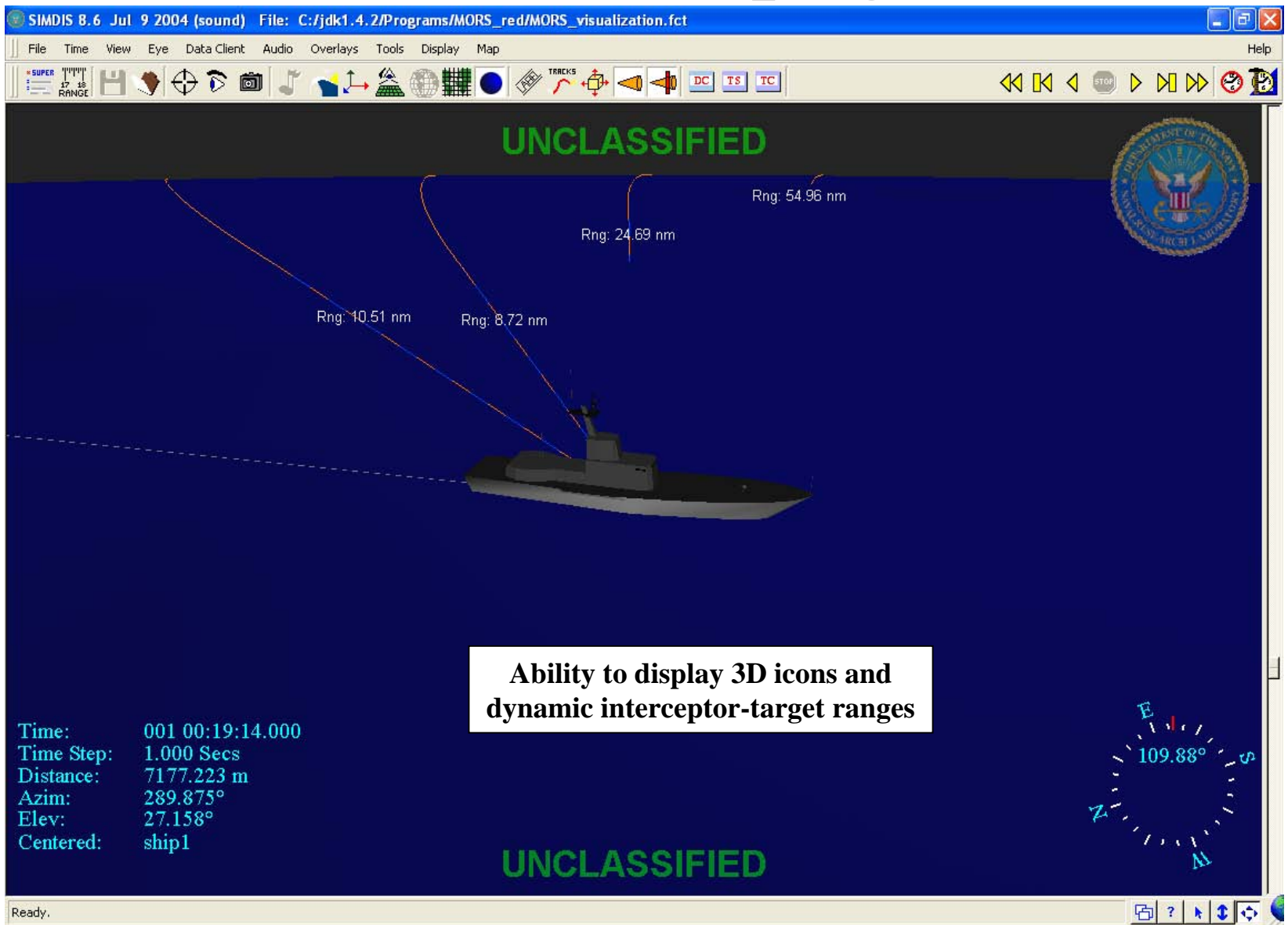
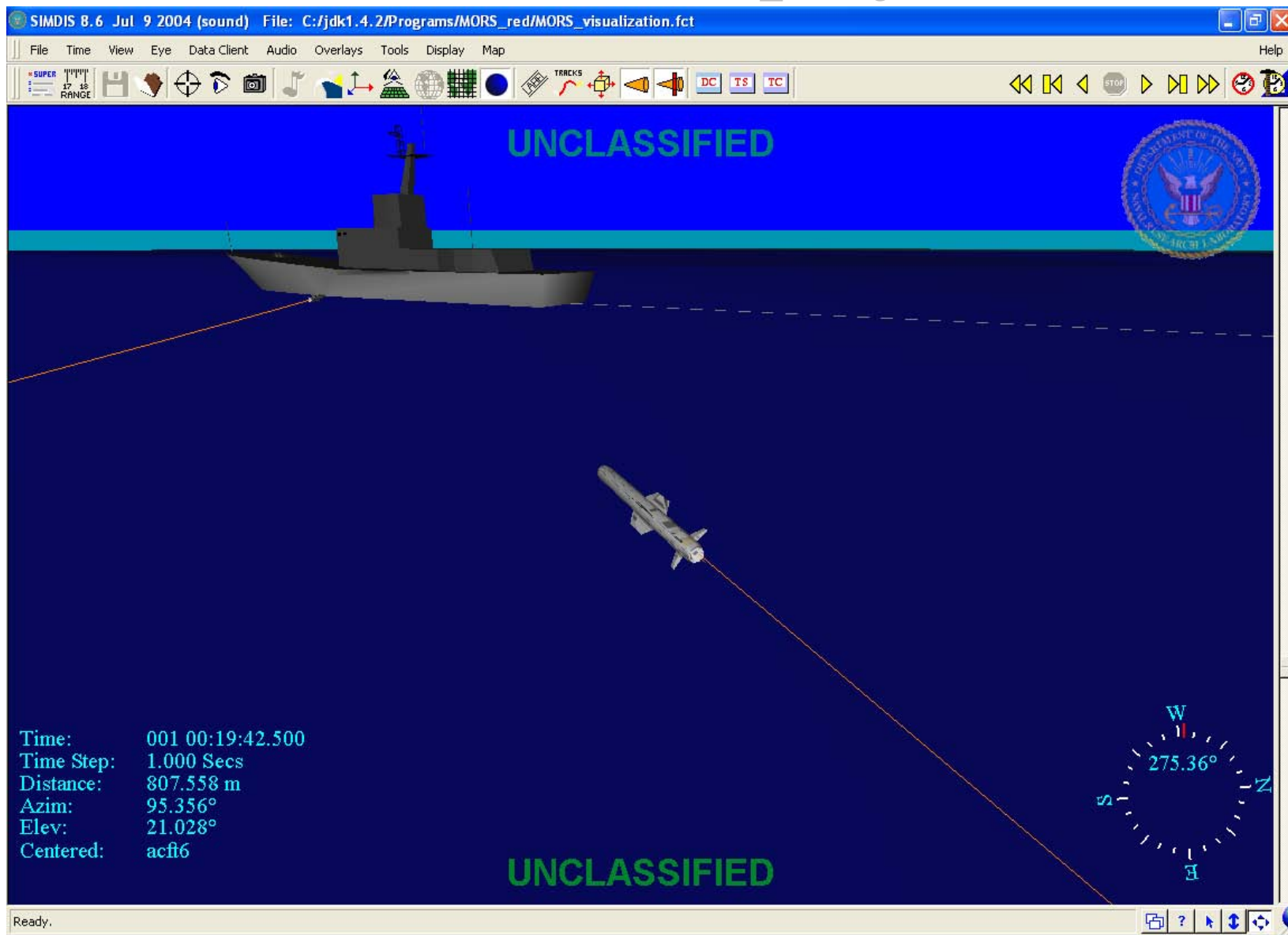Plot of red track left to go at intercept

SIMDIS Display
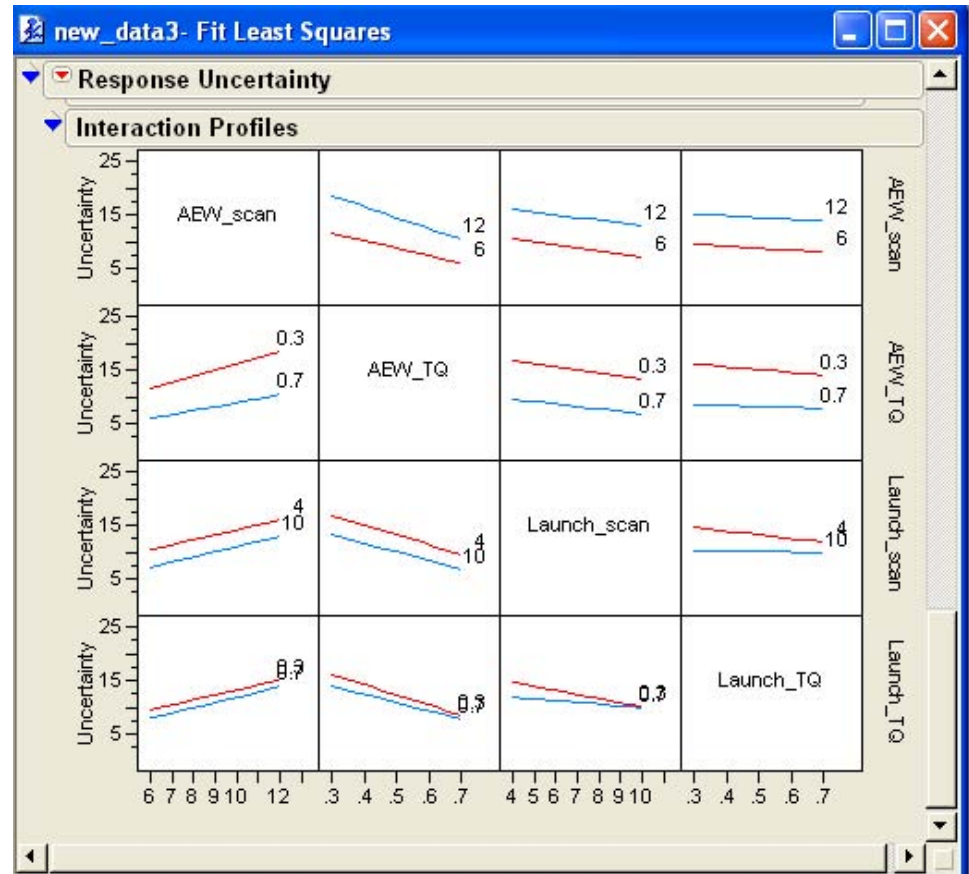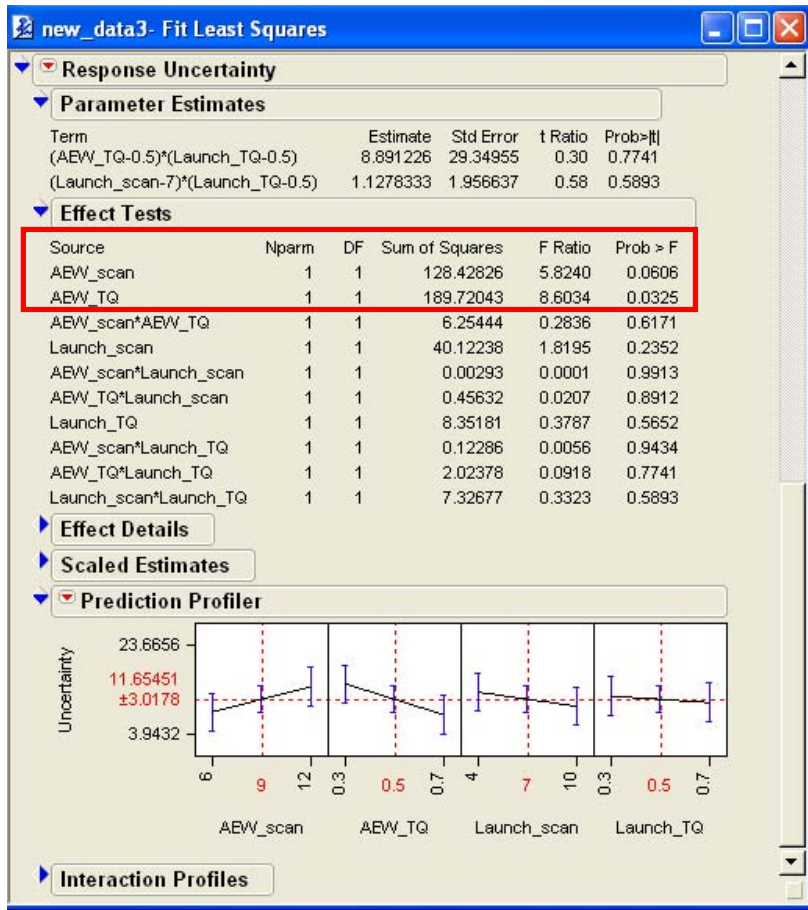
SIMDIS Display

SIMDIS Display

SUW Run Analysis using SAS JMP Software

- SAS JMP may be utilized to show a dependency of the response to several scenario variables

- Through the use of statistical methods, the significant variables or interactions between multiple variables that may be discovered for further analysis

SUW Run Analysis Using JMP

This example shows that the surveillance scan rate and "tracker quality" (probability of detect and how much "uncertainty penalty" is reduced with each successful detection) are most significant factors. Little interaction between cross products.
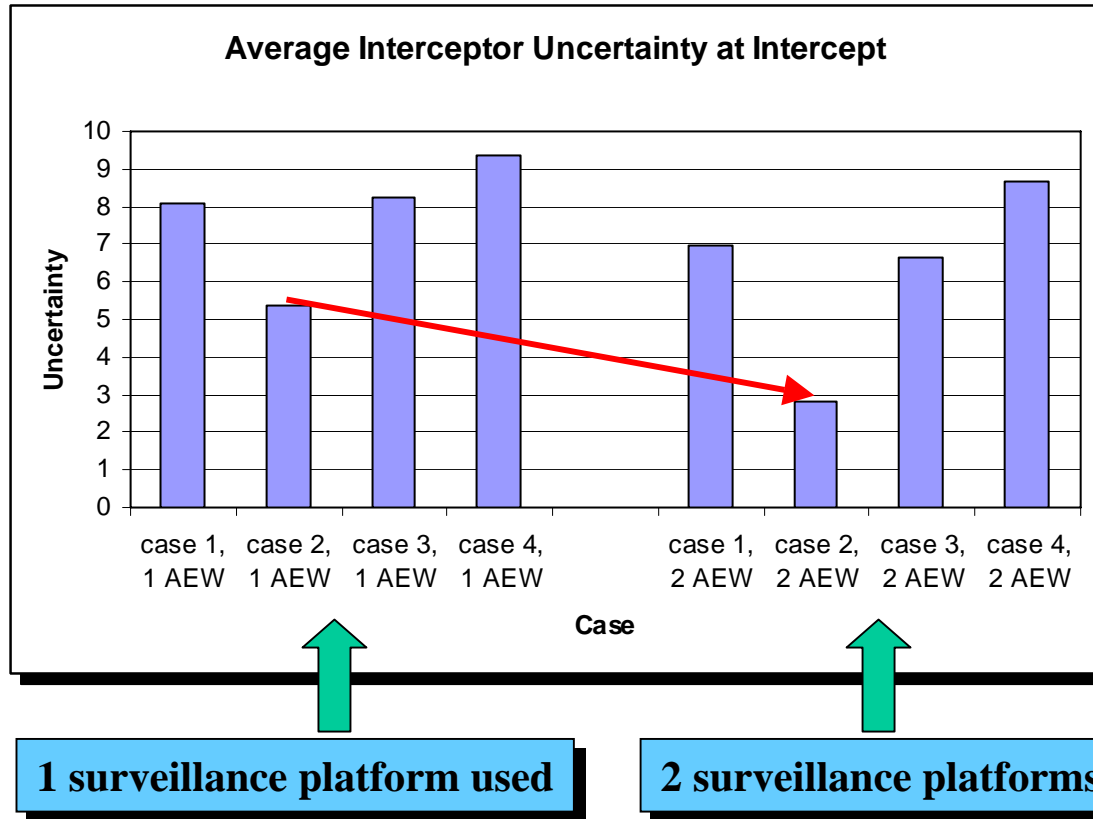
SUW Run Analysis of # of Surveillance Platforms

- Test hypothesis of adding two surveillance to the scenario

- Examine the "uncertainty penalty" at intercept

- Quantify this improvement

- This improvement is also dependent on the quality of additional surveillance
  - If you add a poor platform to the mix, it may get worse

Surveillance Assets Utility for SUW Scenario

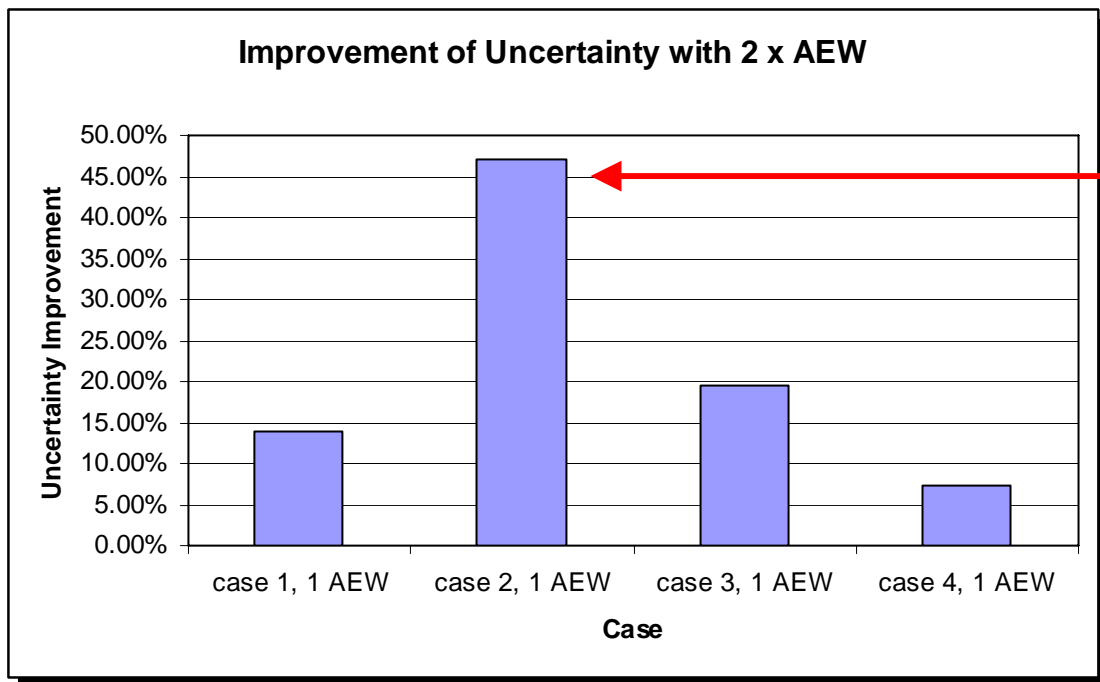**Average Interceptor Uncertainty at Intercept**

1 surveillance platform used

2 surveillance platforms used

The average "uncertainty penalty" shows a decrease when two surveillance platforms are used within the same case

Surveillance Utility Quantification for SUW Scenario

Improvement of Uncertainty with 2 x AEW

	Scan rates	Track Quality
case 1	good scan	low TQ
case 2	good scan	good TQ
case 3	bad scan	good TQ
case 4	bad scan	low TQ

Good scan rate is half the revisit time over a bad scan rate

Good TQ reduces "uncertainty penalty" double over a bad TQ

Quantify this improvement in "uncertainty penalty" with using two surveillance platforms over one. See notes on the case configurations. It should be intuitive that adding an additional "good" surveillance platform provides more value than a "bad" one. From the graph, you could investigate if a better track quality may indeed be better than increasing the sensor scan rate.

Conclusion

- The objective of this project was to develop a methodology to allow a system of systems analysis to be performed

- There are many different tools that contribute to the overall analysis that may be used

- There are many applications for this methodology to be applied
  - Surface Warfare
  - Undersea Warfare
  - Expeditionary Warfare

- This project is also intended to discover additional questions during the scenario analysis for follow up with increased investigative abilities